UNPUBLISHED PRELIMINARY DATA

Grant No. NsG-499

Project "Hiam"

D. G. N.

N65 88440
(ACCESSION NUMBER)
8
(PAGES)
OR 61233
(NASA CR OR TMX OR AD NUMBER)

FACILITY FORM 602

none

Informal Report Covering the Period
July - November 1964

Mr. Joseph Sirutis, under a National Science Foundation fellowship for undergraduate research, and guided by members of Project Hiam, undertook a study of the escape of atmospheric gases from Mars. He presented his preliminary results at a seminar in the School of Engineering and Science, New York University.

Two candidates for the Master's degree were advised by members of the project during preparation of their theses on atmospheric waves and on chemical reactions in the nocturnal ionosphere.

Research scientists supported by the grant have prepared the following summaries of their work during the period July - November 1964.

S. I. Rasool

I. HEAT BUDGET OF EARTH-ATMOSPHERE SYSTEM

The study of the heat budget of the earth-atmosphere system, utilizing the Tiros radiation data, was continued in collaboration with Dr. C. Prabhakara. Part of the results on the derived heat balance of the atmosphere and oceans was presented at the International Symposium on Radiation (sponsored by the I.U.G.G.) held at Leningrad, August 5-12, 1964. Geophysical Sciences Laboratory Report No. 65-1, entitled "Radiation studies from meteorological satellites", summarizes these results.

II. ATMOSPHERE OF MERCURY

A study of the structure of the atmosphere of Mercury was also carried out during the past few months in collaboration with Dr. Stan Gross and Mr. Wayne McGovern. The effect of the possible presence of CO_2 on the temperature of the exosphere of Mercury has been investigated. The flux of the escaping particles on Mercury has been computed and it has been shown that if trace amounts of CO_2 are present here, as reported by recent Russian measurements, it may be possible to explain the presence of an atmosphere with a pressure of up to 10 mb. This result may have an important bearing on the recent observations that the temperature of the permanently dark side of Mercury may be as high as 300°K. The mechanism of transport of heat from the bright side to the dark side in such a case is atmospheric circulation. These results on Mercury were reported at the Fourth Western National meeting of the American Geophysical Union held at Seattle, Washington, December 28-30, 1964.

Joseph S. Hogan

Two areas of interest were investigated theoretically in collaboration with Dr. C. Prabhakara of the Goddard Institute for Space Studies, one dealing primarily with the atmosphere of Mars, the other with the atmosphere of the Earth.

I. OZONE AND CARBON DIOXIDE HEATING IN THE MARTIAN ATMOSPHERE

The first problem concerned a comparison of the roles of ozone and carbon dioxide as heating agents in the Martian atmosphere and the radiative equilibrium temperature distribution obtained when various amounts of these gases are present.

This investigation was prompted by recent high-resolution infrared spectroscopic measurements by Kaplan, Münch and Spinrad (1964) which resulted in estimates of surface pressure and atmospheric composition of the planet Mars differing considerably from those previously given. In the light of those findings, the radiative equilibrium temperature structure of the atmosphere of the planet was reexamined, with the absorption of solar energy in the ultraviolet and visible by oxygen and ozone and in the near infrared by carbon dioxide included in the calculation of atmospheric heating.

The transmission functions of carbon dioxide were theoretically calculated making use of a "statistical" model for band absorption. These transmission functions were then used to evaluate the absorption of solar energy in the near infrared and to investigate the radiative transfer in the far infrared. The theoretical band parameters involving the line intensity and mean ratio of the line half-width to line spacing were derived using the transmittance tables of carbon dioxide presented by Stull, Wyatt and Plass (1964).

The basic photochemical theory of ozone production was used to determine a vertical ozone distribution consistent with the radiative equilibrium temperature structure. The equation of radiative transfer was numerically integrated avoiding the empirical relationships commonly involved in the pressure dependence of carbon dioxide absorption. The infrared flux transmittance was also calculated without any simplifying assumptions.

The approach to the radiative transfer problem was not a "time-marching" one in which a final solution requires the rate of heating to become zero. Instead, it was treated as a steady state problem in which equality between absorbed and emitted energies for all levels is required at each step.

Radiative equilibrium temperatures from the surface to the 100 km level were calculated. For surface temperatures ranging from 230°K to 270°K, surface pressures from 10 mb to 50 mb and carbon dioxide amounts from 40 atm to 70 atm, the "tropopause" is found at levels below 10 km. Within these limits of surface pressure and temperature and carbon dioxide amounts, the temperature above the tropopause steadily decreases toward a value of about 155°K in the upper layers. The results indicate definitely that no temperature maximum is produced by the absorption of solar energy in the untraviolet by ozone or in the near infrared by carbon dioxide in the Martian atmosphere. The maximum ozone number density is found at the surface of Mars with a gradual decrease upward. The total amount of ozone present is about one-tenth of the amount found in the Earth's atmosphere (about 0.3 cm atm). The total ultraviolet energy absorbed in the Martian atmosphere by oxygen and ozone is comparable to the near infrared energy absorbed by carbon dioxide. However, the vertical distribution of absorbed energy shows that below about 20 km oxygen and ozone absorption is comparable to carbon dioxide absorption, while above this level carbon dioxide absorption becomes much larger.

This work resulted in a paper entitled "Ozone and carbon dioxide heating in the Martian atmosphere" which was presented at the International Symposium on Atmospheric Ozone in Albuquerque, New Mexico in early September 1964. The paper has been accepted for publication in the Journal of Atmospheric Sciences.

II. EQUILIBRIUM TEMPERATURE DISTRIBUTION OF THE MESOSPHERE AND LOWER THERMOSPHERE

The second area of research concerned the processes governing the temperature structure of the Earth's atmosphere up to altitudes of 100 km and, in particular, the regions known as the mesosphere and lower thermosphere.

In this work, infrared transfer by both ozone and carbon dioxide was considered, with the band parameters for the 9.6μ ozone band obtained by analysis of Walshaw's measurements (1957). Moreover, the Doppler broadening of the spectral lines was taken into account and the effects of non-local thermodynamic equilibrium were considered. Neglect of these two processes had limited the region of validity of results obtained in our previous work to below 75 km. Their inclusion permitted reliable calculations to at least the 100 km level.

Using an expression derived by Harris (1948), a table was compiled of the fractional absorption Torentz-Doppler convolution line as a function of path length and pressure for the range of pressures and optical paths encountered in the atmosphere. This table was fed into the computer so that by suitable interpolation, the exact value of the absorption for a given path length and pressure could be obtained.

The problem of non-local thermodynamic equilibrium was taken into account by finding a functional form for the pressure dependent ratio of the source function to the Planck function. It is known that at high levels in the atmosphere, collisions are not frequent enough to maintain a Boltzmann distribution among the energy levels of the molecules. As a result, the source function of the atmosphere departs from the Planck function in the vicinity of 75 km. Curtis and Goody (1956) have calculated both the distribution of the source function and of the Planck function in the atmosphere, and from their results an analytic expression for the ratio was obtained.

The calculated temperature profiles obtained from this study agree very well with those observed. Of particular interest is the appearance of the mesopause in the vicinity of 80 km. We observe that this temperature minimum results from the increased capacity of carbon dioxide to control the temperature of the atmosphere at these levels due to the Doppler broadening of the spectral lines. Were it not for the Doppler effects, the atmosphere at these levels would be found at a much higher temperature. The efficiency of carbon dioxide as a cooling mechanism decreases above the mesopause due to the effects of non-local thermodynamic equilibrium, so that the atmosphere responds strongly to solar heating by oxygen absorption and the temperature increases with the height.

A paper describing the nature of this work entitled "Equilibrium temperature distribution in the mesosphere and lower thermosphere" was presented at the 45th Annual Meeting of the American Meteorological Society in New York City in January 1965, and is now being prepared for publication.

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Joel S. Levine

I. CLOUD COVER ANALYSIS FROM TIROS DATA

During the summer I continued to assist Dr. A. Arking of the Goddard Institute for Space Studies on his energy-angle distribution analysis of Tiros visible radiation, and its applications to the study of Tiros cloud cover photographs. The technique for analysis of cloud cover consists of estimating the cloud threshold value on a computer output series of prints. This method has been described by Arking (Science, Vol. 143, No. 3606, pp. 569-572).

Results of this study were presented by Arking in a paper, "Global distribution of earth albedo and cloud cover" at the New York Meeting of the American Meteorological Society, January, 1965.

II. OXYGEN AND OZONE CONCENTRATION IN THE UPPER ATMOSPHERE

Under the supervision of Dr. Arking and Dr. James C. G. Walker of the Goddard Institute for Space Studies, I studied the feasibility of determining the oxygen and ozone concentration of the upper atmosphere by extinction of stellar ultra-violet radiation, as observed by an orbiting satellite. As a satellite circles the earth, the earth will eclipse or occult a number of stars. By observing the extinction rate of the star's UV flux, we can determine the concentration of the absorbing atmospheric constituents. In order to derive theoretical extinction curves to test the feasibility of this method we must know something about stellar UV flux values. There is considerable contradiction between theoretical and observational values of stellar UV flux. Some recent rocket observations made by the Astrophysics Division of the Goddard Space Flight Center may yield some new data on this problem. Another problem encountered was the high intensity UV airglow recently observed by rockets. It is our belief that a narrow-beam spectrometer will filter out the bright diffuse UV airglow and "see" only the stellar UV flux. Using a computer model of the oxygen distribution in atmosphere devised by Walker, we are calculating some theoretical extinction curves for oxygen absorption of UV at different wavelengths. This technique may prove applicable in determining the distribution of absorbing constituents in any planetary atmosphere by a fly-by space probe.

III. VARIABILITY OF SOLAR UV RADIATION

Under the supervision of Dr. S. I. Rasool, I have been investigating the effects of possible variations in solar near UV radiation on the photochemical equilibrium of the earth's atmosphere. A satellite experiment proposed by Rasool to observe this spectral range has been adopted by the Goddard Space Flight Center as a future Nimbus satellite experiment. (Proposal for Measuring Time Variations in the Solar Ultraviolet Radiation by an Earth Satellite, Appendix I of Effects of Assumed Changes in the Near Ultra-violet Radiation on the Photochemical Distribution of Atmospheric Ozone and on the Heating Rates in the Stratosphere, by S. I. Rasool, 1963). In connection with this satellite experiment, I accompanied Dr. Rasool to the Goddard Space Flight Center, Greenbelt, Maryland, on October 6, 1964, to discuss this project with Goddard scientists and experimenters.

In an effort to find a possible index of solar UV variability, we made a statistical study of 10.7 cm solar radio emission. Solar radio emission from 1947 to 1957 was studied in order to determine if a 26-month period (corresponding to the recently detected periodicity of the stratosphere) could be found. Power spectrum analysis and a 12-month running mean analysis did not show a 26-month periodicity, although the analysis did suggest a 6-month periodicity in 10.7 cm solar radio emission. It is our belief that 3 cm radio emission which originates lower in the solar atmosphere, closer to the levels of UV emission, may be a better index of UV variability.

Wayne E. McGovern

The months of July and August were spent on a variety of short term projects in order to gain a cross section view of the type of research being conducted at the Goddard Institute for Space Studies. These projects were mainly concerned with temperature and composition models of the earth's upper atmosphere, under the direction of Dr. James C. G. Walker.

As part of this orientation period I attended the Institute's summer course in Space Physics given by Dr. Robert Jastrow at Columbia University.

In September I aided Dr. Walker in attempting to determine the coefficients of recombination, between 120 and 450 kilometers, for the four ions of atomic oxygen, molecular oxygen, molecular nitrogen, and nitric oxide. This problem was abandoned when it became obvious that inherent cumulative errors in the computer program would render very poor results for the coefficients.

Following this, under the direction of Dr. A. Arking, I investigated mathematical techniques for determining the detailed absorption spectrum of carbon dioxide. This project likewise showed little promise due to limitation in computer techniques.

My next project was a consideration of the high microwave radiation temperature emitted from the dark side of Mercury. This project examined four possible mechanisms for explaining this phenomenon. They were free emission from the ionosphere, surface wind friction, electrical dust storms, and heat transport. This project was under the supervision of Dr. S. I. Rasool, who is currently investigating the upper atmosphere of Mercury. As a continuation of this project I am presently constructing several temperature profiles of Mercury's lower atmosphere, with the aim of incorporating these profiles into Dr. Rasool's research.

Richard S. Greenfield

ATMOSPHERIC BREAKING WAVES

Since the last informal progress report I visited at the National Severe Storms Laboratory (NSSL) of the U. S. Weather Bureau at Norman, Oklahoma. The purpose of this trip was to locate data which hopefully may be used to verify some of the theoretical results which have already been obtained. Two cases were chosen which may be used for this verification effort. The meso-network data for these two cases have been obtained on microfilm from NSSL. Supporting synoptic data were also obtained from the National Weather Records Center, Asheville, North Carolina. The analysis of this data is now in progress.

Although there has been some effort made to examine, theoretically, the turning effect on a propagating wave as it passes over a three-dimensional hill, the problems connected with an additional dimension have, thus far, not been solved. It is hoped that this turning effect may be examined, observationally, in the two case studies now being performed. Some theoretical insight into this effect may be obtained from a linearized model which is being investigated.

The major effort in the next six months will be to complete the analysis of the two case studies and the correlation of the analysis with the theoretical results.

Eugene E. A. Chermack

OPTICAL CONSTANTS OF MASCAGNITE

During the early part of the period I helped organize and attended a Conference on the Optical Properties of Aerosols. This conference, under the joint sponsorship of New York University and the U. S. Army Electronics Laboratory, took place in October 1964 at Sterling Forest, N. Y. Evidence was presented at the conference to indicate that high level aerosols can have a significant effect on downward looking radiometers.

The past several months have been used for the setting up, alignment and calibration of a model 113 Perkin-Elmer monochromator.

At present the monochromator prism employed is rock salt (NaC 1) which has a useful transmission range of roughly 1-15 microns. Since the absorption bands of $(NH_4)_2SO_4$, the aerosol material under study, lie mainly within this region, it is probable that the NaC 1 prism will be used for the remainder of the experiments. Several other prism materials have uniform transmission through this range and even beyond 15 microns into the infrared; however, this desirable characteristic is offset by higher cost, higher water solubility and/or generally lower transmission than rock salt.

Calculations have been carried out to determine the dispersion characteristics and the resolution obtainable with the rock-salt optics in this particular monochromator system.

Runs were made during the past two months for familiarization, calibration and noise studies. In the 1-2 micron region a mercury-arc lamp was used for calibration. Atmospheric CO_2 and polystyrene film were used to calibrate the instrument in the 2-5 micron range and atmospheric H_2O vapor was used in the 5-8 micron range. Calibration of the system into the 15 micron region will be effected through the use of a standard gas cell filled with NH_3.

Experimental runs using mascagnite samples will begin shortly. The first sample type will be a pressed pellet of the pure compound which can be prepared locally at little or no expense. In addition efforts are being made to obtain single crystals of the pure substance should the pellet technique yield ambiguous or unrepeatable results.